AQA
Realising potential

GCSE
BIOLOGY
(8461)

Required practical handbook

The methods provided in this Required practical handbook are suggested examples, designed to help your students fulfil the apparatus and techniques requirements outlined in the specifications. Written papers will include questions requiring knowledge gained from carrying out the specified practicals.

Please note: it is the Apparatus and techniques requirements which are compulsory and must be fulfilled. Teachers are encouraged to adapt or develop activities, resources and contexts to suit their equipment and to provide the appropriate level of engagement and challenge for their own students.

Version 5.3 July 2025

Contents

Introduction

The purpose of this handbook

The required practical activities listed in the GCSE Biology specification (8461) have been written to ensure that students have the opportunity to experience all of the Apparatus and Techniques (AT) criteria required by Ofqual.

In this guide we **suggest** methods for carrying out the required practical activities to give ideas and guidance to help you plan the best experience for your students. **None of these methods are compulsory.** However, you must ensure that you carry out a sufficient variety of practical work to give your students the opportunity to experience all aspects of the AT criteria required by Ofqual. The methods we have suggested will enable you to do this, but we strongly encourage you to adapt them to fit the needs of your students and the resources you have available.

The methods we suggest are deliberately familiar, using apparatus and techniques that are readily available in most schools. All of the methods suggested have been written by practising teachers and trialled by specialist lab technicians, who have included sample results when appropriate.

Covering the AT criteria

Students must be given the opportunity to experience all of the biology AT criteria during their GCSE science course, regardless of the awarding body whose specification they study.

Individual practical activities will not necessarily cover all aspects of an AT statement, ie it is only by doing all of the required practical activities that all aspects of each AT statement will be covered. The teacher and technician notes indicate which aspects of an AT statement the method we suggest covers.

We are keen to encourage teachers to use alternative methods that support students to develop their understanding of the AT statements. More detailed advice, additional activities and alternative methods can be found on the CLEAPSS website.

Whichever method you use, it is your responsibility to check that you have covered all of the aspects of the AT statements.

The GCSE practical science statement

There is no practical skills endorsement at GCSE level, unlike that at A-level. Instead, the head of each school or college will need to sign the AQA practical science statement to confirm that reasonable opportunities have been given to ensure that each student has:

- completed the required practical activities detailed in the specification
- made a contemporaneous record of such work undertaken during the activities and the knowledge, skills and understanding derived from those activities.

The head of centre will need to return the signed statement to us by the date we will publish on our website. We will also contact schools and colleges directly with the deadline date and send timely reminders if we don't receive the form. Failure to send this form counts as malpractice/ maladministration and may result in formal action or warning for the school or college.

Teachers should agree with their head of school what evidence he or she requires to be confident in signing the declaration.

If a student is absent from a required practical activity and doesn't catch up with the work they have missed, it may compromise their overall grade as 15% of the available examination marks are practical work related.

Risk assessment

Schools and colleges are responsible for ensuring that appropriate safety procedures are followed, and should undertake full risk assessments.

Comprehensive information on safe use of practical apparatus, techniques and associated chemicals etc is available on the CLEAPSS website.

Suggested websites to support with practical work

Association for science education

Field studies council

Getting practical

Practical Biology

Society of Biology

STEM

Student worksheets

Within the student worksheets we have included a number of tasks which will challenge students to think about their practical work and/or related theory. The questions are **not** example examination questions and are expected to be edited and expanded on by teachers.

Required practical activities per specification

The below table shows which required practical activities must be covered by each of the five GCSE science specifications.

Required practical activity	Synergy	Trilogy	Biology	Chemistry	Physics
Microscopy	✓	✓	✓		
Osmosis	✓	✓	✓		
Enzymes	✓	✓	✓		
Food tests	✓	✓	✓		
Photosynthesis	✓	✓	✓		
Reaction time	✓	✓	✓		
Field investigations	✓	✓	✓		
Plant responses			✓		
Decay			✓		
Microbiology			✓		
Making salts	✓	✓		✓	
Temperature changes	✓	✓		✓	
Rates of reaction	✓	✓		✓	
Chromatography	✓	✓		✓	
Water purification	✓	✓		✓	
Electrolysis	✓	✓		✓	
Neutralisation				✓	
Identifying ions				✓	
Specific heat capacity	✓	✓			✓
Resistance	✓	✓			✓
I-V characteristics	✓	✓			✓
Density	✓	✓			✓

Force and extension	✓	✓			✓
Acceleration	✓	✓			✓
Waves	✓	✓			✓
Radiation and absorption	✓	✓			✓
Thermal insulation					✓
Light					✓

Teacher and technician notes

Microscopy

Use a light microscope to observe, draw and label biological specimens.

	Trilogy	Synergy	Biology
RPA	1	3	1
Specification reference	4.1.1.2	4.1.3.2	4.1.1.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 7	use of appropriate apparatus, techniques and magnification, including microscopes to make observations of biological specimens and producing labelled scientific drawings

Materials

For the basic method

- a microscope
- prepared slides of plant and animal cells.

Students should make clear, labelled diagrams of the cells they observe and include the magnification.

Investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.

	Biology
RPA	2
Specification reference	4.1.1.6

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length and area
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of living organisms (plants or animals) to measure physiological function and responses to the environment
AT 8	the use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem solving contexts including continuous sampling in an investigation

Materials

For the basic method

- a nutrient agar plate that has been inoculated with bacteria
- a heatproof mat
- filter paper discs
- three antiseptics (such as mouthwash, TCP, and antiseptic cream)
- disinfectant bench spray
- 1% Virkon disinfectant
- forceps
- clear tape
- hand wash
- a wax pencil or permanent marker
- access to an incubator (set to 25 °C).

Technical information

Students should be aware of the need for good aseptic techniques but they do not need to prepare the plates themselves.

Results from this method are likely to be variable and inconclusive. It may be helpful to show students an exemplar set of results produced by the technician for comparison.

Cultures of *E. coli* bacteria, nutrient agar, and suitable disinfectants for the bench spray and the 'discard beaker' can be bought from educational suppliers. The instructions, and any risk assessment information, which accompany them should be followed carefully. *E. coli K12* grows well in 24 hours at 24°C but gives very pale growth. You could use *Micrococcus luteus* instead of *E. coli* which is bright yellow and grows much better at 25°C.

Plastic petri dishes should be used as these can be destroyed by melting in an autoclave or sterilising pressure cooker, in a specialist autoclave bag (or roasting bag), immediately after obtaining the results. Discs can be cut from filter paper using a hole-punch. Glass spreaders are made by bending a 3–4 mm diameter glass rod into an L-shape.

Antiseptics should be provided in small beakers so that the disks can be dipped into the antiseptic easily with forceps.

Plates should be secured with extra sticky tape before student viewing. It is important that condensation in the plates can still escape. See CLEAPSS guidance on how to attach the sticky tape.

For sterilising glass pipettes, syringes or glass spreaders, wrap in greaseproof paper or foil and heat treat at 160 °C for 2 hours. Sterile plastic pipettes, syringes and spreaders can be purchased.

1% Virkon disinfectant should be used as they have validation of sterilisation.

If ethanol sterilisation is to be used, the ethanol should be kept well away from any naked flames.

Additional information

Students do not need to prepare the plates themselves or spread the lawn of the bacteria. They do need to be aware of the use of aseptic techniques, and the techniques shown in the table below could be demonstrated.

Technique	**Additional information**
Flaming the neck of the culture bottle	This must be done whilst still holding the pipette and the lid of the culture bottle in your other hand (neither should be placed down on the bench at any point). The bottle must not be held still in the flame as the glass will crack – it should be rotated as it is very briefly passed through the flame.
Lifting the lid of the agar plate at an angle	The lid should only be opened at the side facing the Bunsen burner to avoid contamination.
Placing drops of culture from the pipette onto the agar.	This needs to be done while carefully holding the lid over the plate.

Spreading the bacteria thoroughly around the agar plate right to the edges	This is best done by holding the glass spreader still up to the edge of the plate and rotating the plate. The lid of the plate must be held over it at the same time to avoid contamination.
Placing the filter paper discs onto the agar plate in the right positions	Students should hold the first disc with the forceps. They should lift the lid of the agar plate at an angle (as before) and place the disc flat onto the central dot in the first third of the plate. The lid of the agar plate should be replaced whilst the next disc is collected. This is repeated so that all three discs are in position.

It is important to work carefully but quickly to minimise contamination.

Time can be saved by using commercially produced antibiotic discs rather than having the students prepare the discs themselves.

Clear zones are not always perfectly circular so students should measure the diameter twice (at 90° to each other) and calculate a mean diameter and area for each clear zone. Plates should be checked after 24 hours to see that zones have appeared. 48 hours gives good clear zones. If plates cannot be measured after this time they can be stored in a fridge for a couple of days.

AQA Technician results

Type of antiseptic	**Diameter of clear zone in mm**		
	1	**2**	**Mean**
Kitchen cleaner	11.0	13.0	12.0
Antiseptic liquid	17.0	14.0	15.5
Hand sanitiser	19.0	20.0	19.5
Bleach	24.0	26.0	25.0
Toiler cleaner	7.0	8.0	7.5
Pine disinfectant	10.0	10.0	10.0

Osmosis

Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

	Trilogy	Synergy	Biology
RPA	2	4	3
Specification reference	4.1.3.2	4.1.3.3	4.1.3.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to measure and record a range of measurements accurately including length, mass and volume of liquid
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 5	measurement of rate of reaction by a variety of methods including an uptake of water

Materials

For the basic method

In addition to standard laboratory equipment:

- a potato
- a cork borer
- a ruler with mm scale
- labels or a permanent marker
- paper towels
- a sharp knife or scalpel
- a top-pan balance accurate to at least 0.01 g
- a range of sugar or sodium chloride solutions (0.25–1.0 mol/dm^3)
- distilled water.

The class will need to collect results from solutions of at least five different concentrations if students wish to be able to plot a graph and calculate the rate of uptake of water. A balance measuring to 0.01 g is necessary to get a measurable change in a short time. The length of time that the potato cylinders are left in the sugar or salt solutions can be adjusted to suit lesson timings.

If a water bath is included and tubes left for 30 minutes at 30°C it will give measurable changes in mass and length whilst allowing students experience of controlling temperature.

The method has been worked through using sugar solutions by our Technician Advisor. The table below shows the data obtained, which can be used as examples or for students to use to gain further practice in the calculation and graph plotting.

	1.0 mol/dm^3 sugar solution	**0.75 mol/dm^3 sugar solution**	**0.5 mol/dm^3 sugar solution**	**0.25 mol/dm^3 sugar solution**	**Distilled water**
Initial mass in g	6.08	5.97	6.10	5.92	5.98
Final mass in g	4.05	3.82	4.00	4.45	6.48
Change in mass in g	–2.03	–2.15	–2.10	–1.47	+0.5
Percentage change in mass	-33.4	-36.0	-34.4	-24.8	+8.4
Initial length in cm	3.2	3.3	3.3	3.1	3.2
Final length in cm	2.5	2.7	2.8	3.2	3.7
Change in length in cm	–0.7	–0.6	–0.5	+0.1	+0.5
Percentage change in length	–21.9	–18.2	–15.2	+3.2	+15.6

Technical information – to make up sugar solutions of various concentrations

Make up a 1.0 mol/dm^3 sucrose solution by adding distilled water to 342.4 g of sugar (dissolve by heating) and making up to 1 litre in a volumetric flask. Dilute this appropriately to produce a range of solutions from 1.0 to 0.25 mol/dm^3. This should provide enough of each solution for a class as each student needs 10 cm^3 of each, in addition to 10 cm^3 of distilled water.
Ensure that potato cylinders do not have any skin on them as this affects the movement of water molecules.

Food tests

Use qualitative reagents to test for a range of carbohydrates, lipids and proteins. To include: Benedict's test for sugars, iodine test for starch and Biuret reagent for protein.

	Trilogy	**Synergy**	**Biology**
RPA	3	7	4
Specification reference	4.2.2.1	4.2.1.5	4.2.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 2	safe use of apprioprate heating devices and techniques including the use of a bunsen burner and a water bath

Materials

For the basic method

In addition to standard laboratory equipment:

- a sample of food to be tested
- pestle and mortar
- stirring rod
- filter funnel and filter paper
- five 100 cm^3 beakers
- a conical flask
- distilled water
- four test tubes
- labels or marker pen
- water bath (electric or beaker of water and Bunsen burner*)
- Benedict's solution
- iodine solution (0.01 mol/dm^3)
- ethanol
- Biuret solution.

*** use of the Bunsen burner to satisfy AT2**

This is usually carried out as a circus activity. There is a range of different ways of approaching this. You may choose to use specific foods to show positive test outcomes or to use a range of foods that are tested with all reagents to allow a more investigative approach. This will depend on the experiences of the students at Key Stage 3.

The basic student worksheet will describe how to carry out each of the separate food tests but this can be adapted as appropriate to ensure students are challenged.

Technical information

Benedict's qualitative reagent

Benedict's solution or DNSA (see CLEAPSS) should be used to test for reducing sugars. Benedict's solution can also be purchased from suppliers and is very stable when stored.

Glucose, lactose and maltose are reducing sugars and give a positive test. Sucrose is a non-reducing sugar and does not give a positive result.

No hazard warning symbol is required on the bottle as the concentrations of each of the constituents are low.

Qualitative Biuret reagent

This is best made up as Biuret A and Biuret B, which are quite stable, and add as a two-stage test. See CLEAPSS.

Iodine solution

A 0.01 mol/dm^3 solution is suitable as a test reagent for starch. It may be purchased ready-made or made up following the instructions on CLEAPSS.

Ethanol solution

Please note that there are alternative approaches to testing for lipids including the simple rubbing of the sample onto filter paper which will show a positive test if the paper goes transparent.

Suggested foods for testing

- **Carbohydrates:** potato, bread, rice, cooked noodles, biscuits, sugar, apples, flour, corn starch.
- **Lipids:** olive oil, sesame seed oil, grape seed oil, margarine, butter, lard, milk (full fat, semi-skimmed, skimmed), egg white solution, egg yolk solution.
- **Proteins:** whole cheese, meat, tofu, apple, potato, cooked beans, eggs, yeast, milk, yogurt.

Note: grated cheese that you can buy in prepared packs from a supermarket often contains starch, which can confuse students if you test foods for a range of things.

Enzymes

Investigate the effect of pH on the rate of reaction of amylase enzyme.

	Trilogy	**Synergy**	**Biology**
RPA	4	20	5
Specification reference	4.2.2.1	4.7.4.7	4.2.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including time, temperature, volume of liquids and pH
AT 2	safe use of appropriate heating devices and techniques including use of a Bunsen burner and water bath or electric heater
AT 5	measurement of rates of reaction by a variety of methods including using colour change of an indicator

Materials

For the basic method

In addition to standard laboratory equipment:

- 10 test tubes
- a test tube rack
- water bath (electrical or Bunsen burner and beaker) at 35 °C
- a spotting tile
- a 5 cm^3 measuring cylinder
- pasteur pipettes, syringes or 5 cm^3 measuring cylinders
- a glass rod
- a stopwatch or stopclock
- starch solution (1%)
- fungal amylase solution (0.1%)
- labelled buffered solutions at a range of pH values
- labels
- iodine solution (0.01 mol/dm^3)
- a thermometer.

This is one example of how enzyme activity can be measured. As amylase often generates unreliable data you could use this enzyme as a demonstration and students could then use suitable alternatives eg catalase. Amylase activity should be tested before using in class to ensure that results can be obtained in a reasonable time.

A 0.1% solution of amylase gives good results, but this can be diluted further if the reaction is still too fast.

The method suggested has been trialled with several classes, and all were able to obtain results. The method was trialled using 0.1% fungal amylase, 1% starch and with pH5, 6, 7 and 8 prepared buffers (CLEAPSS) and buffers purchased from suppliers. There was no noticeable difference between results. The following results were obtained.

pH of solution	**Time for amylase to completely break down the starch in seconds (at 35^{o}C)**
5	29
6	46
7	160
8	>300

The amount of amylase can be reduced to 1 cm^3 to increase the time taken for the starch to be broken down.

Technical information

Amylase will slowly lose activity so it is best to make up a fresh batch, using the powdered enzyme, for each lesson. Otherwise any results collected on different days will not be comparable.

Starch suspension should also be made fresh. This can be done by making a cream of 5g of soluble starch in cold water and pouring into 500 cm^3 of boiling water. Stir well and boil until you have a clear solution.

A 0.01 mol/dm^3 iodine solution is suitable as a test reagent for starch. It may be purchased ready-made or made up following the instructions on CLEAPSS.

Buffered solutions should be made using CLEAPSS *(The Universal Buffer: Recipe 1)*. The optimum pH for amylase is pH 6. A range of buffered solutions between pH 5 and pH 8 would be appropriate. Buffers can be purchased from suppliers but ensure they do not contain any dye.

It is best to check that the amylase breaks down the starch at an appropriate rate before students do this experiment. At around the optimum pH, the end point should be reached within 1–2 minutes, but this will depend on the amylase used.

Some amylases used in detergents are not denatured even at temperatures close to boiling water. Some amylases are also inhibited by buffers. Fungal amylase is quite reliable.

Photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

	Trilogy	**Synergy**	**Biology**
RPA	5	10	6
Specification reference	4.4.1.2	4.2.2.6	4.4.1.2

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately, including time and volume of a gas
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment
AT 5	measurement of rates of reaction by a variety of methods including the production of gas

Materials

For the basic method

- a beaker
- filter funnel
- a 1 cm^3 or 10 cm^3 measuring cylinder
- freshly cut 10 cm piece of pondweed
- a light source
- a metre rule
- a stopwatch.

This practical is difficult to achieve measurable volumes of oxygen within routine time but is useful to demonstrate to students the principles of photosynthesis. It might be helpful to support students understanding of the rate of photosynthesis with the use of a simulation or similar resources.

Technical information

Native species of *Cabomba* are no longer available to schools because it is classed as an invasive species and has been removed from sale. Other varieties of pondweed such as *Elodea* could be used in this investigation which can be bought from tropical fish shops and some large garden centres. If *Elodea* is used, place the plant in a beaker of water in front of a lamp for 2–3 hours before starting the investigation.

High-intensity light sources (at least 1000 lumens) need to be used for the practical. Low energy light bulbs should not be used as the light intensity may be too low to promote measurable photosynthesis.

If the pondweed tubes are placed in a beaker of water (at least 250 cm^3) then the use of a heat shield is usually unnecessary. Temperature of the water can be monitored with a thermometer to ensure no temperature rise.

If no bubbles appear from the cut end of the pondweed when placed closest to the light source, cut a few millimetres off the end or, if necessary, use a new freshly cut piece.

Reaction time

Plan and carry out an investigation into the effect of a factor on human reaction time.

	Trilogy	Synergy	Biology
RPA	6	8	7
Specification reference	4.5.2	4.2.1.6	4.5.2.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of a living organisms (plants or animals) to measure physiological functions and responses to the environment

Materials

Students work in pairs for this investigation. Each pair should have:

For the basic method

- a metre rule
- a chair
- a table.

Technical information

This method investigates the effect of practising an event on reaction time.

Ruler measurements can be converted to reaction times using the conversion table on page 22.

Additional information

Students can use the conversion table on page 23 to calculate reaction time from their measurements. Pre-converted strips can be taped to metre rulers to save time.

This method has been trialled with students and the following results obtained.

Drop test attempt	Ruler measurements in cm		Reaction times in seconds	
	Person 1	Person 2	Person 1	Person 2
1	48	32	0.31	0.26
2	44	30	0.30	0.25
3	37	27	0.28	0.23
2	29	28	0.24	0.24
5	26	25	0.23	0.23
6	34	21	0.26	0.21
7	34	26	0.26	0.23
8	20	25	0.21	0.23
9	32	29	0.26	0.24
10	19	27	0.20	0.23

Conversion table

Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)	Reading from ruler (cm)	Reaction time (s)
1	0.05	21	0.21	41	0.29	61	0.35	81	0.41
2	0.06	22	0.22	42	0.29	62	0.36	82	0.41
3	0.08	23	0.22	43	0.30	63	0.36	83	0.41
4	0.09	24	0.22	44	0.30	64	0.36	84	0.41
5	0.10	25	0.23	45	0.30	65	0.36	85	0.42
6	0.11	26	0.23	46	0.31	66	0.37	86	0.42
7	0.12	27	0.23	47	0.31	67	0.37	87	0.42
8	0.13	28	0.24	48	0.31	68	0.37	88	0.42
9	0.14	29	0.24	49	0.32	69	0.38	89	0.43
10	0.14	30	0.25	50	0.32	70	0.38	90	0.43
11	0.15	31	0.25	51	0.32	71	0.38	91	0.43
12	0.16	32	0.26	52	0.33	72	0.38	92	0.43
13	0.16	33	0.26	53	0.33	73	0.39	93	0.44
14	0.17	34	0.26	54	0.33	74	0.39	94	0.44
15	0.18	35	0.27	55	0.34	75	0.39	95	0.44
16	0.18	36	0.27	56	0.34	76	0.39	96	0.44
17	0.19	37	0.28	57	0.34	77	0.40	97	0.45
18	0.19	38	0.28	58	0.34	78	0.40	98	0.45
19	0.20	39	0.28	59	0.35	79	0.40	99	0.45
20	0.21	40	0.29	60	0.35	80	0.40	100	0.45

Investigate the effect of light or gravity on the growth of newly germinated seedlings.

	Biology
RPA	8
Specification reference	4.5.4.1

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements including length and time
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 4	safe and ethical use of living organisms (plants and animals) to measure physiological functions and responses to the environment

Materials

For the basic method to fulfil the ATs

- white mustard seeds
- three petri dishes
- cotton wool
- a ruler
- water
- access to a light windowsill and a dark cupboard.

Technical information

It should be emphasised that this investigation is about the responses of germinated seeds and not on factors affecting germination. Therefore students could be supplied with dishes already prepared with germinated seeds such as white mustard (*Brassica alba*).

Cotton wool should be damp but not in excess water. The amount of cotton wool and water needed should be determined before students do the experiment. Cotton wool pads for make-up removal are suitable and are all the same size and thickness.

Seeds will require a day or so to germinate (depending on how warm it is). Alternative seeds, such as cress or *Brassica rapa*, could be used instead of white mustard seeds. However, white mustard seeds are bigger and easier to handle.

You can purchase pots of cress and split them into smaller units.

Partial light can be achieved by alternating a day on the windowsill with a day in the dark cupboard.

Field investigations

Measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.

	Trilogy	**Synergy**	**Biology**
RPA	7	12	9
Specification reference	4.7.2.1	4.4.2.4	4.7.2.1

There are two parts to this investigation:

1. Investigating the population size of a plant species using random sampling.
2. Investigating the effect of a factor on plant distribution using a transect line.

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements accurately including length and area
AT 4	safe and ethical use of a living organism to measure physiological responses to the environment
AT 6	application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field

Materials

For the basic method

- a quadrat (25 × 25 cm or 50 x 50 cm)
- a 30 m tape measure
- a light meter
- a clipboard.

Technical information

1. Investigating the population size of a plant species using random sampling

Choose an area of grass with sufficient space to carry out this survey. You will need at least 400 m^2 to accommodate a class.

Help students to identify the species being investigated.

Lay out two tape measures (or marked strings) 20 m in length so that they form right angles. These two tape measures represent the two sides of a 20 m × 20 m square. Place two bags containing numbers at the point where the two tape measures meet.

Organise the students into groups of three. One student will select a number from one of the bags and move that distance along the tape. A second student will select a number from the other bag and move that distance along the other tape. The third student with the quadrat uses the other two students as markers in order to place the quadrat on the ground. The group then return their numbers to the bags. The group then return their quadrat to count and record the number of different plant species in the quadrat.

Get students to repeat this process in order to count the number of plant species in a chosen number of quadrats. Students can then use this data to estimate the population of the survey area.

For example, in a case where 50 daisies were counted in ten samples, the total population can be estimated using this equation:

$$\text{Estimated population size} = \frac{\text{total area}}{\text{area sampled}} \times \text{number of daisies counted}$$

The area sampled from 10 quadrats is 0.25 m × 0.25 m = 10 × 0.0625 m^2 = 0.625 m^2

The total area of the survey = 20 m × 20 m = 400 m^2

$$\text{Estimated population} = \frac{400}{0.625} \times 50 = 32{,}000$$

2. Investigating the effect of a factor on plant distribution using a transect line

A transect line from a tree to an open area can be used to record the change in the number of a particular species as light intensity changes. Students can record either percentage grass cover or the number of daisies in each quadrat. Students need to lay out a tape measure in a straight line so that a quadrat can be placed at regular intervals.

In this method, students should use a light meter to measure the light intensity at each quadrat. This will allow students to plot a graph of distribution against light intensity. You will need to demonstrate how to use a light meter, you could access a light meter via a phone app.

A shorter transect line could be used if space is limited and quadrats could be placed closer together.

Suggested alternative approaches from teachers and technicians

- Alternative investigations may be possible using micro-habitats such as trees, pathways, hedges, walls, grave stones, ponds, soil, etc.
- Students could investigate the distribution of lichens on tree trunks or walls at different distances from a main road.
- Students could also investigate the distribution of woodlice in relation to soil water content, light intensity or temperature.

Decay

Investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.

	Biology
RPA	10
Specification reference	4.7.2.3

By using this method your students will have the opportunity to develop the following aspects of the biology AT skills	
AT 1	use of appropriate apparatus to make and record a range of measurements including time and temperature
AT 3	use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes
AT 5	measurement of rates of reaction by a variety of methods including a colour change of indicator

Materials

For the basic method

- a small beaker containing full fat milk or single cream (not UHT)
- a small beaker containing sodium carbonate solution (0.05 mol/dm^3)
- a small beaker containing 5% lipase solution
- 250 cm^3 beakers, to be used as water baths
- boiling tubes
- a boiling tube rack
- a marker pen
- 10 cm^3 plastic syringes
- a stirring thermometer
- stop clock
- Cresol red, in a dropper bottle
- an electric kettle, for heating water
- ice, for investigating temperatures below room temperature.

Technical information

Sodium carbonate solution, 0.05 mol/dm^3. Make with 5.2 g of anhydrous solid or 14.2 g of washing soda per litre of water. See CLEAPSS: it is an **irritant** at concentrations over 1.8 mol/dm^3.

Lipase solution should be freshly made, but it can be kept for a few days in a refrigerator.

Cresol red is an indicator that is purple in alkaline solutions of about pH 8.8. When the pH drops below pH 7.2 Cresol red becomes yellow. It can be purchased but if made from solid it should be used within a few weeks.

Because the natural process of decay in milk is slow, it is difficult for students to monitor in normal class time. In this method we have suggested an approach that speeds up the process through the addition of lipase. Therefore the procedure suggested should serve as a '**model**' for the investigation of decay in milk. The fall in pH in natural decay would be due to the production of lactic acid. In this model, the fall in pH is due mainly to the production of fatty acids as a result of enzyme action. A suggestion of suitable range of temperatures would be 20 – 60^{o}C (optimum temperature 35-45^{o}C).

Additional information

Ideally, at least five different temperatures should be investigated.

AQA Technician results

Temperature of milk in °C	**Time taken for solution to turn yellow, in seconds**			
	Your results	**Class repeat 1**	**Class repeat 2**	**Mean**
20	365	360	345	
35	21	22	26	
45	16	19	22	
55	>10 mins			
65	>10 mins			

Student worksheets

Microscopy

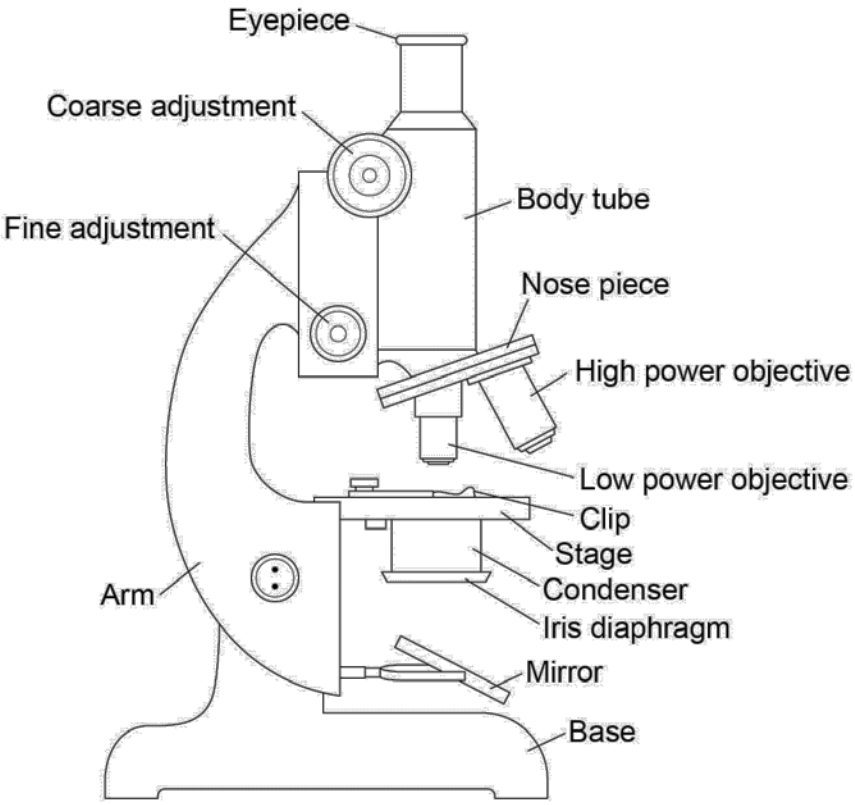
Use a light microscope to observe, draw and label biological specimens.

In this practical you will:

- use an optical microscope to look at and draw the cells on your microscope slide
- identify structures within the cells
- make a note of the magnification used.

Using a microscope to look at animal and plant cells

The diagram shows a typical microscope.



Some microscopes have a built-in light instead of a mirror.

Apparatus

- a microscope
- prepared slides of plant and animal cells.

Method

1. Put the slide on the microscope stage.
2. Turn the nose piece to select the lowest power objective lens (this is usually ×4 objective lens). The end of the objective lens needs to **almost** touch the slide.
3. Turn the coarse adjustment knob to move the lens towards the slide. Look from the side (**not** through the eyepiece) when you are adjusting the lens.
4. Now look through the eyepiece. Slowly turn the coarse adjustment knob in the direction to increase the distance between the objective lens and the slide. Do this until the cells come into focus.
5. Slightly turn the fine adjustment knob to bring the cells into a clear focus. Use the low power objective lens (totalling ×40 magnification) to look at the cells.
6. When you have found some cells, turn the nose piece to switch to a higher power lens (×100 or ×400 magnification).
7. You will have to use the fine adjustment knob again to bring the cells back into focus.
8. Make a clear, labelled drawing of some of the cells. Make sure that you draw and label any component parts of the cell. Use a pencil to draw the cells.
9. Write the magnification underneath your drawing. Remember to multiply the objective magnification by the eyepiece magnification.

Cell drawings and magnification

Animal cell	**Plant cell**

Task

Write down the names of the parts of both the animal and plant cell that you cannot see in the light microscope field of view. Write a sentence to explain the function of these parts.

Investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.

In this practical you will:

- use aseptic technique to put discs of filter paper soaked in different antiseptics onto petri dishes containing bacteria
- measure the zone of inhibition around the growing colonies to compare the effect of the antiseptics.

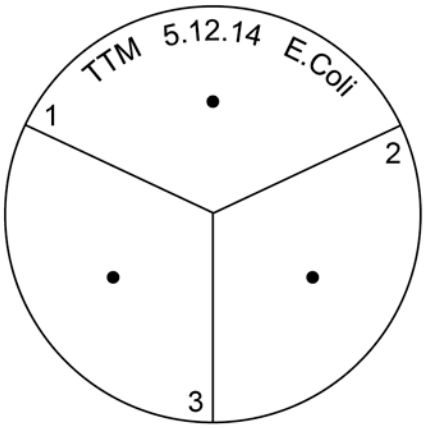
Apparatus

- a nutrient agar plate inoculated with bacteria
- filter paper discs
- three antiseptics (such as mouthwash, TCP, and antiseptic cream)
- disinfectant bench spray
- forceps
- clear tape
- antibacterial hand wash
- a wax pencil or permanent marker
- ruler.

Method

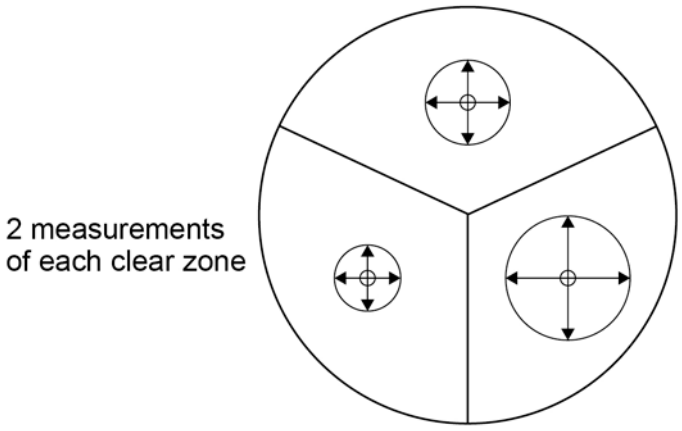
1. Make sure your hands and work space are thoroughly clean before and after the experiment.
2. Spray the bench where you are working with disinfectant spray. Then wipe with paper towels.
3. Use the wax pencil or permanent marker to mark the bottom of the nutrient agar plate (not the lid) as shown in the diagram below. Make sure that the lid stays in place to avoid contamination.
    - divide the plate into three equal sections and number them 1, 2 and 3 around the edge
    - put a dot into the middle of each section
    - add your initials, the date and the name of the bacteria.

Your plate will look like this:



4. Wash your hands with the antibacterial hand wash.
5. Put a different antiseptic onto each of the three filter paper discs, being careful to shake off excess liquid to avoid splashing.
6. Carefully lift the lid of the agar plate at an angle away from your face. Do not open it fully.
7. Use the forceps to carefully put each disc onto one of the dots you drew on with the wax pencil.
8. Make a note of which antiseptic is in each section.
9. Secure the lid of the agar plate in place using two small pieces of clear tape.

   Do **not** seal the lid all the way around as this creates anaerobic conditions. Anaerobic conditions will prevent the bacteria from growing and can encourage some other very nasty bacteria to grow.
10. Incubate the plate at 25 °C for 48 hours.
11. Measure the diameter of the clear zone around each disc. Measure again at 90° to your first measurement, then calculate the mean diameter.



12. Record your results in a table like this one:

Type of antiseptic	Diameter of clear zone in mm		
	1	**2**	**Mean**

Task

From the mean diameter measurements calculate the cross sectional area of the clear areas around the bacterial colonies.

Conclusion

What type of antibiotic was most effective on the bacterial growth?

Health and safety

Identify the main hazards in this investigation and suggest methods to reduce the risk of harm.

Osmosis

Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.

In this practical you will:

- prepare samples of potato and place them in different concentrations of sugar or sodium chloride (salt) solution
- make measurements of mass and length of your samples before and after soaking them in the solutions.

Apparatus

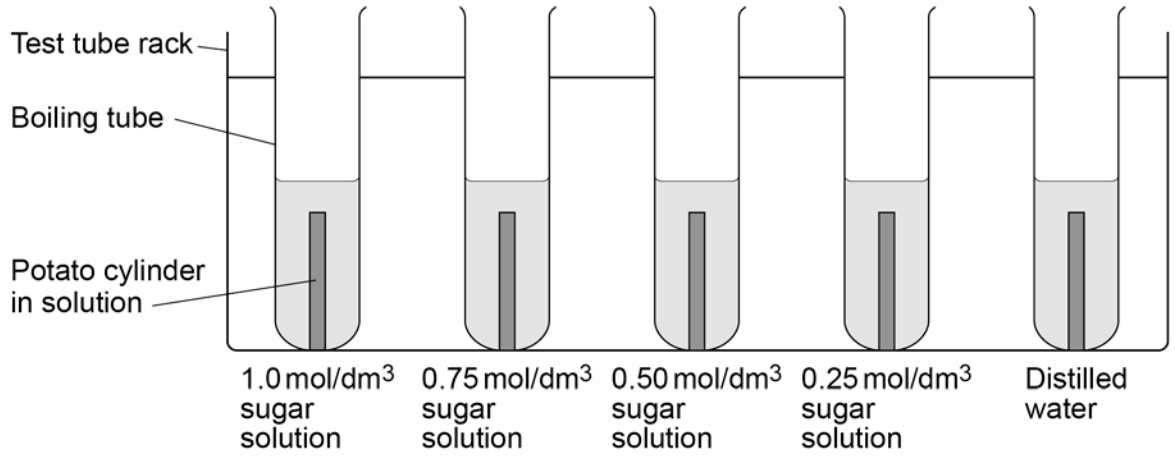
- a potato
- a cork borer
- a ruler
- a 10 cm^3 measuring cylinder
- labels
- five boiling tubes
- a test tube rack
- paper towels
- a sharp knife or scalpel
- a white tile
- a range of sugar or salt solutions
- distilled water
- a top-pan balance accurate to at least 0.01 g.

Method

1. Use a cork borer to cut five potato cylinders of the same diameter.
2. Use the knife to trim off any potato skin on each potato cylinder. Then trim each potato cylinder so that they are all the same length.
3. Accurately measure the mass of each potato cylinder.
4. Accurately measure the length of each cylinder.
5. Record your measurements in a table like the one shown over the page.

	1.0 mol/dm^3 sugar solution	0.75 mol/dm^3 sugar solution	0.5 mol/dm^3 sugar solution	0.25 mol/dm^3 sugar solution	Distilled water
Initial mass in g					
Final mass in g					
Change in mass in g					
Percentage change in mass %					
Initial length in cm					
Final length in cm					
Change in length in cm					
Percentage change in length %					

6. Measure 10 cm^3 of each concentration of sugar or salt solution and put into boiling tubes. Label each boiling tube clearly.
7. Measure 10 cm^3 of the distilled water and put into the fifth boiling tube. Label the boiling tube clearly.
8. Add one potato cylinder to each boiling tube.



9. Leave the potato cylinders in the boiling tubes for a chosen amount of time.
10. Remove the potato cylinders from the boiling tubes and carefully blot them dry with the paper towels.
11. Measure the new mass and length of each potato cylinder again. Record your measurements for each concentration in your table.

Analysis of your results

- Calculate the change in mass and length of each potato cylinder. Record your results in your table.
- Calculate the percentage change in mass and length of each potato cylinder and record your results in your table.
- Write a paragraph to state what has happened and how this relates to the theory of osmosis in cells.

Food tests

Use qualitative reagents to test for a range of carbohydrates, lipids and proteins. To include: Benedict's test for sugars, Iodine test for starch and Biuret reagent for protein.

In this practical you will:

use qualitative reagents to test for the presence of carbohydrates, lipids and proteins in a range of foods.

Test for carbohydrates

The Benedict's test for sugars

Apparatus

- food sample
- a test tube
- Benedict's solution
- traditional water bath to include Bunsen burner use
- thermometer
- pipettes.

Method

1. Set up your traditional water bath set up using a Bunsen burner.
2. Put some of the food sample into a test tube.
3. Add a few drops of Benedict's solution to the sample in the test tube.
4. Put the test tube in the water bath at a minimum of 80 °C for about 5 minutes.
5. Note down any colour change in your table of results.

The Iodine test for starch

Apparatus

- food sample
- a test tube
- iodine solution
- pipettes.

Method

1. Put some of the food sample into a test tube.
2. Add a few drops of Iodine solution.
3. Note down any colour change in your table of results.

Test for lipids

Apparatus

- food sample
- a test tube
- ethanol
- distilled water.

Method

1. Put some of the food sample into a test tube.
2. Add a few drops of distilled water.
3. Add a few drops of ethanol.

   Care: Ethanol is highly flammable. Keep the solution away from any flames.
4. Shake the solution gently.
5. Note what you see in your table of results.

Test for protein

Apparatus

- a test tube
- a 10 cm^3 measuring cylinder
- Biuret solution A and Biuret solution B.

Method

1. Put some of the food sample into a test tube.
2. Add 1 cm^3 of Biuret solution A and 1 cm^3 of Biuret solution B to the test tube.

   Care: Biuret solution contains copper sulphate, which is poisonous, and sodium hydroxide, which is corrosive. Handle the solution with care. Wash immediately if you spill it on your skin, and wipe up any spills.
3. Shake the tube gently to mix.
4. Note any colour change in your table of results.

Recording data

Record your results in the table below.

Name of food tested	Colour produced with Benedict's solution	Colour produced with iodine solution	Cloudy layer produced with ethanol	Colour produced with Biuret solution

Write a conclusion to state which food groups are present one of the food samples you tested and an explanation of how you know this.

Investigate the effect of pH on the rate of reaction of amylase enzyme.

In this practical you will:

- use the enzyme amylase to break down starch at different pH values
- measure the pH of different solutions
- use a water bath to keep reacting solutions at a constant temperature
- use a continuous sampling technique
- use iodine solution as an indicator of the breakdown of starch into sugars.

Apparatus

- 10 test tubes
- a test tube rack
- a water bath
- a thermometer
- a spotting tile
- a 5 cm^3 measuring cylinder
- pasteur pipettes
- a glass rod
- a stop clock
- starch solution
- amylase solution
- iodine solution
- labelled buffered solutions at a range of pH values
- labels.

Method

1. Heat your water bath to 35 °C.
2. Put 2 cm^3 of each buffered solution into individual, separate test tubes. Label each tube with the pH of the solution.
3. Label 5 test tubes ‘Starch’ and add 4 cm^3 of starch solution into each tube.
4. Put a thermometer in one of the starch test tubes to monitor the temperature. Leave the thermometer in this tube throughout the experiment.
5. Add 10 cm^3 of Amylase solution into another test tube. Label the tube ‘amylase’.
6. Put all the test tubes into the water bath.
7. Allow the solutions to reach 35 °C.
8. While the solutions are reaching the required temperature, put one drop of Iodine solution into each depression on your spotting tile.

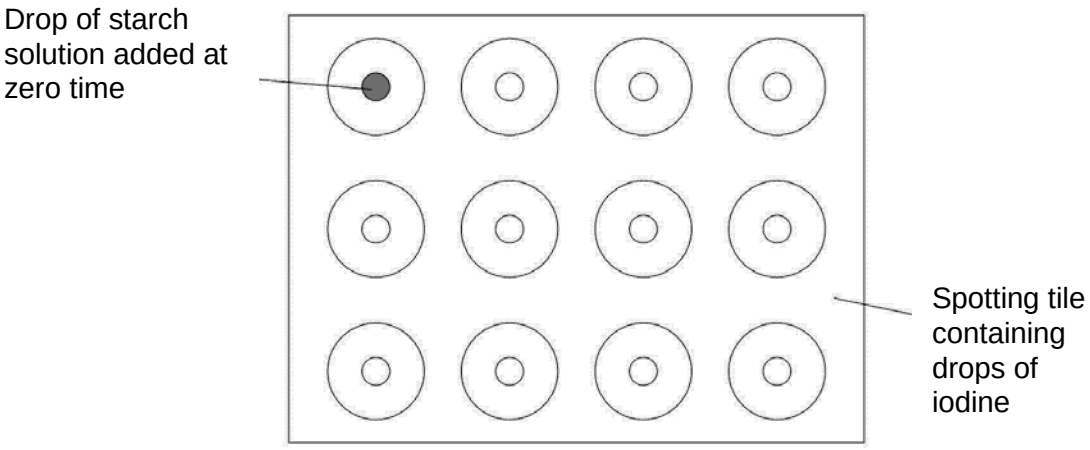
Put a drop of starch solution in the first depression of the tile. This is your 'zero time' mixture. You will use this as a comparison of colour for your test buffers. Starch gives a blue-black colour with iodine, and the iodine stays brown if all the starch has broken down to glucose.

9. When all the tubes have reached 35 °C take one of the tubes of starch from the water bath and add the 2 cm^3 of your first pH buffered solution. Stir the mixture with a glass rod.

10. Use the pipette to add 2 cm^3 of amylase solution to the mixture. Start the stopclock as soon as you add the amylase. Keep stirring the mixture with the glass rod.

11. After 10 seconds, remove one drop of the mixture with a glass rod.

12. Put this drop on the second depression of your spotting tile.



13. Rinse the glass rod with water.

14. Every 10 seconds, use the glass rod to remove one drop of the mixture.

    Put each drop onto the iodine solution in the next depression on the spotting tile.

    Remember to rinse the glass rod with water after putting each drop on the spotting tile.

15. Keep sampling every 10 seconds until the iodine does not change colour.

16. Record your results in a table like this one:

pH of solution	**Time for amylase to completely break down the starch in seconds**

Repeat steps 10–17 with both of your other pH buffered solutions.

Task

Enzymes are **biological catalysts**. Explain what happens to the starch when the amylase is added.

Investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.

In this practical you will:

measure the volume of oxygen produced by the pondweed as the light intensity changes as the light source is moved.

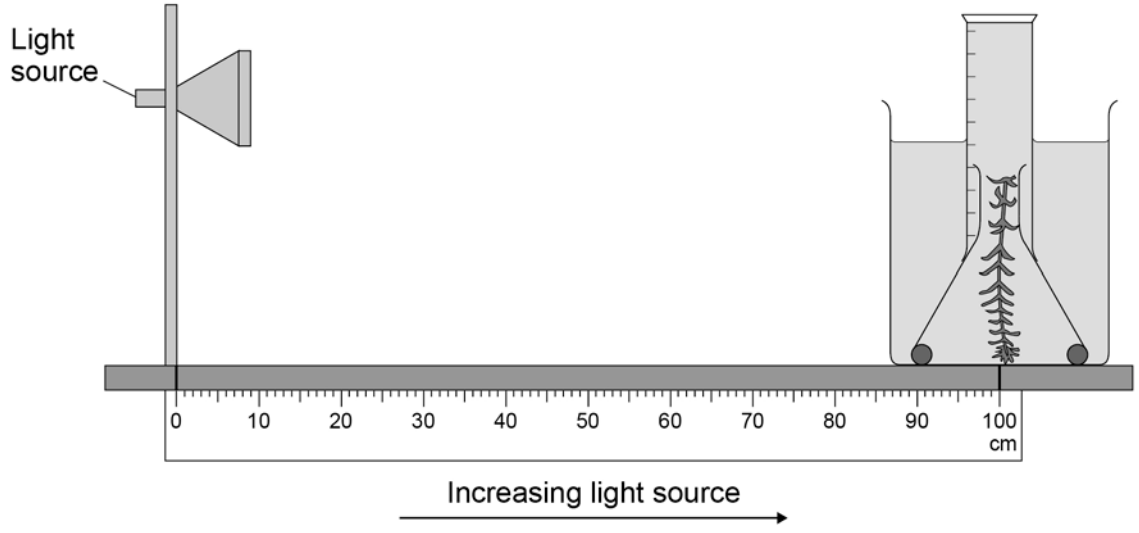
Apparatus

- a beaker
- a filter funnel
- plasticine
- a measuring cylinder (1 or 10cm^3)
- a 10 cm piece of pondweed
- a light source
- a metre rule
- a stop watch.

Method

1. Put your 10 cm piece of pond weed (cut edge at top) into a beaker of water.
2. Cover the pondweed with an inverted filter funnel – raised off the bottom of the beaker with plasticine.
3. Fill the measuring cylinder with water and gently position as in the diagram.
4. Use the ruler to position the beaker of pondweed 1 metre away from the light source.

   Your experiment should look like this:



5. Start the stop watch and:
    a. count and record the number of bubbles released in three minutes
    b. record the volume of gas produced and collected in the measuring cylinder in the same three minutes.
6. Record your results in a table like this one:

	Increasing light intensity				
	100cm	**80cm**	**60cm**	**40cm**	**20cm**
Number of gas bubbles					
Volume of gas cm^3					

7. Move the light source so that the pondweed beaker is 80 cm away.
8. Refill the measuring cylinder with water and gently position as in the diagram.

    Then repeat steps 5 and 6.
9. Repeat for distances of 60, 40 and 20 cm.

Evaluation

Which method of recording gas collection was most accurate and why?

Reaction time

Plan and carry out an investigation into the effect of a factor on human reaction time.

In this practical you will:

- decide which factor you want to investigate that will have an effect on human reaction time
- work with a partner to use the ruler drop test
- use your results to calculate your reaction time before and after you made the change.

Apparatus

- a metre ruler
- a chair
- a table
- any further equipment needed depending on the factor you are changing.

Investigation

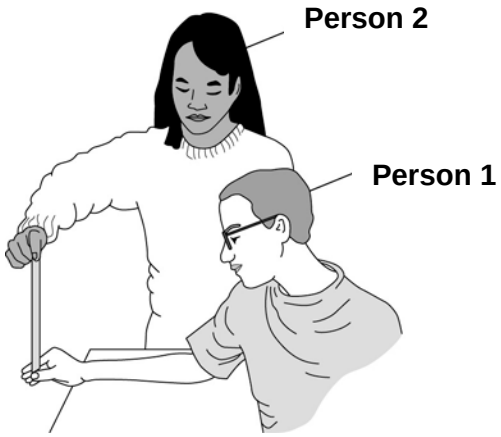
What factor have I decided to change?

How will I change it?

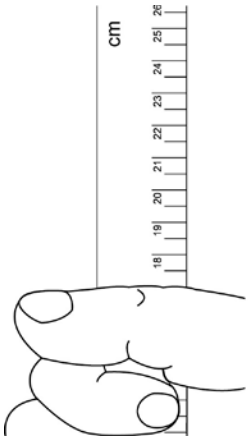
What affect do I think it will have on human reaction time?

Method for standard human reaction time test

1. Work with a partner to do this test. Choose who will be person 1 and who will be person 2.
2. Each of you should use your dominant hand to do this experiment. If you are right handed then your dominant hand is your right hand.
3. Person 1 sits down on the chair, with good upright posture and eyes looking across the room.
4. Person 1 puts the forearm of their dominant arm across the table with their hand overhanging the edge.
5. Person 2 holds a ruler vertically with the bottom end (the end with the 0 cm mark) in between person 1's thumb and first finger. They will tell person 1 to prepare to catch the ruler.



6. Person 1 catches the ruler with their thumb and first finger as quickly as possible when it drops.
7. Record the number on the ruler that is level with the top of person 1's thumb.



8. Have a short rest, then repeat the test several times.

9. Record your results on a table.

Drop test attempt	Ruler measurements in cm				Reaction times in seconds			
	Person 1 Before	Person 2 Before	Person 1 After	Person 2 After	Person 1 Before	Person 2 Before	Person 1 After	Person 2 After
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

10. Repeat the test with Person 2 catching the ruler and Person 1 dropping it.
11. Record Person 2's results on the table.
12. Use a conversion table to convert your ruler measurements into reaction times.
13. Make the change that you are investigating to change human reaction time.
14. Repeat steps 1-9 for each person and record the results in your data table.

Analysing the data

Do your results reflect your hypothesis? Did the factor you changed have any effect on your reaction time?

Consider your own and your partners results. Are your reaction times similar? If not, can you explain why?

What type of errors might have happened to affect your results?

Investigate the effect of light or gravity on the growth of newly germinated seedlings.

- set up three petri dishes with mustard seeds and allow them to germinate
- put each dish of seedlings in a different light intensity for the same period of time
- monitor the height of each seedling at each light intensity.

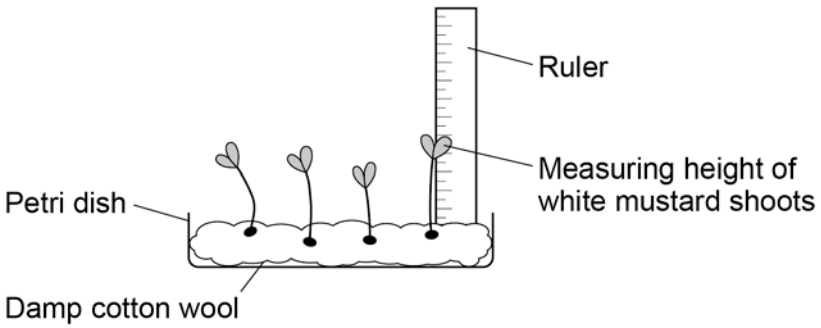
Apparatus

- some white mustard seeds
- three Petri dishes
- cotton wool
- a ruler
- water.

Method

1. Set up three petri dishes containing cotton wool soaked in equal amounts of water.
2. Put ten mustard seeds in each dish.
3. Put the dishes in a warm place. They must **not** be disturbed or moved.
4. Allow the mustard seeds to germinate.

   Water daily with equal amounts of water to each dish.
5. Each dish should have the same number of seedlings after the seeds have geminated. Remove excess seedlings from any dish that has too many.
6. Measure the height of each seedling in mm.



7. Move the petri dishes into position.
    - Put one on a windowsill in full sunlight.
    - Put the second one in partial light.
    - Put the third one in darkness.

8. Measure the height of each seedling every day, for at least five consecutive days.
9. Record the heights in a table like this one:

Day	**Height of seedling in full sunlight in mm**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
1									
2									
3									
4									
5									

You will need a table each for:

- full sunlight
- partial light
- darkness.

Analysis and conclusion

a. Calculate the mean height of the seedlings each day.
b. Plot a graph with:

- 'Mean height in mm' on the y-axis.
- 'Day' on the x-axis.

Your graph should include the data for full sunlight, partial light and darkness.

c. Write a conclusion to state and explain your results, you should include reference to hormones and their distribution in your written answer.

Field investigations

Measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.

In this practical you will:

- work in a group to use a quadrat to estimate the population size of a plant species in a survey area.
- use a transect line and a quadrat to investigate the effect of light intensity on the number of plants in a survey area.

Investigating the population size of a plant species using random sampling

Apparatus

a quadrat.

Method

Your teacher will have prepared a survey area for you and will show you how to identify the plants (eg plantain) you are surveying. You will need to work in groups of three.

1. Collect two numbers, one from each bag.
2. Use the numbers and the tape measures to locate the first position for your quadrat.
3. Lay the quadrat on the ground.
4. Replace the numbers in the bags.
5. Count and record the number of the chosen plant species inside the quadrat.
6. Repeat steps 1–5 until you have recorded the numbers of chosen plant species in ten quadrats.
7. Your teacher will show you how to estimate the population of plantain using the equation

$$\text{estimated population size} = \frac{\text{total area}}{\text{area sampled}} \times \text{number of plantain counted}$$

Task

Design a results table and record the number of each type of chosen species you could see in each of your ten quadrats.

Investigating the effect of light intensity on plant distribution using a transect line

Apparatus

- a quadrat
- a 30 m tape measure
- a light meter.

Method

Your teacher will help you choose a species of plant to identify.

1. Put the 30 m tape measure in a line from the base of a tree to an open area of ground.
2. Put the quadrat against the transect line. One corner of the quadrat should touch the 0 m mark on the tape measure.
3. Count the number of plants inside the quadrat.
4. Use the light meter to measure the light intensity at this position.
5. Record your results in a table like this:

Distance along the transect line in m	**Number of plants in quadrat**	**Light intensity**
0		
5		
10		
15		
20		
25		
30		

5. Move the quadrat 5 m up the transect line and count the number of plants again. Measure the light intensity at this position. Record your results in your table.
6. Continue to place the quadrat at 5 m intervals up the transect line. Count the number of plants and measure the light intensity in each quadrat.

Task

Plot and draw appropriate graphs, selecting appropriate scales for the axes.

Write a sentence to describe the relationship you see in your graphs.

Decay

Investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.

In this practical you will:

- decide on the range of temperatures that you wish to investigate milk decay over, considering the lesson time you have
- use an indicator to monitor the rate of decay of milk.

Apparatus

- a small beaker of full fat milk or single cream
- a small beaker of sodium carbonate solution
- a small beaker of lipase solution
- a 250 cm^3 beaker
- boiling tubes
- a boiling tube rack
- a marker pen
- 10 cm^3 plastic syringes
- a stirring thermometer
- a stop clock
- Cresol red, in a dropper bottle
- an electric kettle, for heating water
- ice, for investigating temperatures below room temperature.

Investigation

What range of temperatures have you chosen to investigate?

What affect do you think changing this variable will have on the rate of decay of milk?

Method

1. Label a boiling tube 'lipase' and add 5 cm^3 of the lipase solution.
2. Label another boiling tube 'milk' and add five drops of the Cresol red solution.
3. Use a calibrated dropping pipette to add 5 cm^3 of milk to the 'milk' boiling tube.
4. Use another pipette to add 7 cm^3 of sodium carbonate solution to the 'milk' boiling tube.

   The solution should be purple.
5. Put a thermometer into the 'milk' boiling tube.
6. Set up a water bath to your first chosen temperature.
7. Put both boiling tubes into the water bath. Wait until the contents reach the same temperature as the water bath.
8. Use another dropping pipette to transfer 1 cm^3 of lipase from the 'lipase' tube to the 'milk' tube.

   Immediately start the stopclock.
9. Stir the contents of the 'milk' boiling tube until the solution turns yellow.
10. Record the time taken for the colour to change to yellow, in seconds.
11. Then repeat the investigation for different temperatures of water bath.
12. Record your results in a table like this one.

Temperature of milk in °C	**Time taken for solution to turn yellow, in seconds**			
	Your results	**Class repeat 1**	**Class repeat 2**	**Mean**

Analysis and conclusion

a. Plot a graph of your results.

b. Write a sentence to state the relationship between temperature and time taken for the indicator to turn yellow.

c. Does this reflect the hypothesis you made before carrying out the practical? Consider in your explanation the shape of your curve and enzyme activity.

Get help and support

Visit our website for information, guidance, support and resources at aqa.org.uk/8461

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